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[List of the Attached Documents]

[Name of the Document] Claims 1

[Name of the Document] Specification 1

[Name of the Document] Drawings 1

[Name of the Document] Abstract 1

[Name of Document] Claims

[Claim 1]

A photomultiplier, comprising: a photocathode emitting electrons in response to incident light; an electron multiplier section electron-multiplies the electrons emitted from the photocathode; an anode for taking out, as a signal, the electrons multiplied in the electron multiplier section,

wherein the electron multiplier section has a groove extending such that the electrons travel in a direction intersecting an electron emitting direction from the photocathode.

[Claim 2]

A photomultiplier according to claim 1, wherein the electron multiplier section performs electron-multiplying by bombarding the electrons with the pair of side walls forming the groove.

[Claim 3]

A photomultiplier according to claim 1 or 2, wherein the side walls of the groove are formed with a protrusion.

[Claim 4]

A photomultiplier, comprising: a photocathode emitting electrons in response to incident light; an electron multiplier section electron-multiplies the electrons emitted from the photocathode; an anode for taking out, as a signal, the electrons multiplied in the electron multiplier section,

wherein the photomultiplier includes a first glass substrate on which the anode is arranged, a second glass substrate on which the photocathode is arranged, and a silicon substrate which is arranged

between the first glass substrate and the second glass substrate and on which the electron multiplier is formed, and

wherein the silicon substrate constitutes a vacuum envelope by being in closely contact with respective of the first glass substrate and the second glass substrate.

[Claim 5]

A photomultiplier according to claim 4, wherein the silicon substrate is joined to the first glass substrate and the second glass substrate by anodic bonding.

[Claim 6]

A photomultiplier according to claim 4, wherein the anode is arranged in a space surrounded by the silicon substrate, and is joined by anodic bonding.

[Claim 7]

A photomultiplier according to claim 4, wherein the electron multiplier section is joined by anodic bonding.

[Claim 8]

A photomultiplier, comprising: a photocathode emitting electrons in response to incident light; an electron multiplier section electron-multiplies the electrons emitted from the photocathode; an anode for taking out, as a signal, the electrons multiplied in the electron multiplier section,

wherein the photomultiplier includes a first substrate on which the anode is arranged, a second substrate on which the photocathode is formed, and a silicon substrate which is arranged between the first substrate and the second substrate and on which the electron multiplier

is formed, and

wherein the first substrate and the silicon substrate, and, the second substrate and the silicon substrate constitute a vacuum envelope by being in closely contact with each other through a glass material, respectively.

[Claim 9]

A photomultiplier according to claim 8, wherein the first substrate is comprised of a silicon material.

[Claim 10]

A photomultiplier according to claim 8, wherein the second substrate is comprised of a glass material, the glass material between the second substrate and the silicon substrate is included in the second substrate.

[Name of Document] Specification

[Title of the Invention] Photomultiplier

[Technical Field]

[0001]

The present invention relates to a photomultiplier.

[Background Art]

[0002]

Photomultipliers (PMT: Photo-Multiplier Tube) have conventionally been known as a photosensor. A photomultiplier comprises a photocathode converting light into electrons, a focusing electrode, an electron multiplier section, and an anode, and is constituted by accommodating them in a vacuum envelope. When light is incident on the photocathode in the photomultiplier, photoelectrons are emitted from the photocathode into the vacuum envelope. The photoelectrons are guided to the electron multiplier section by the focusing electrode, and are multiplied in a cascading manner by the electron multiplier section. As signals, the anode outputs electrons having arrived thereat among those multiplied (see, for example, Patent Document 1 and Patent Document 2).

[Patent Document 1] Japanese Patent No. 3078905

[Patent Document 2] Japanese patent Application Laid-Open No. H4-359855

[Disclosure of the Invention]

[Problems that the Invention is to Solve]

[0003]

As photosensors have been widening the scope of their

application, smaller photomultipliers have been in demand. Then, the present invention has an object to provide a photomultiplier capable of achieving a smaller size thereof.

[Means for Solving the Problems]

[0004]

A photomultiplier according to the present invention comprises: a photocathode emitting electrons in response to incident light; an electron multiplier section electron-multiplies the electrons emitted from the photocathode; an anode for taking out, as a signal, the electrons multiplied in the electron multiplier section, and characterized in that the electron multiplier section has a groove extending such that the electrons travel in a direction intersecting an electron emitting direction from the photocathode.

[0005]

In accordance with the photomultiplier according to the present invention, since the groove of the electron multiplier section extends such that the electrons transmit in a direction intersecting an electron emitting direction from the photocathode, a smaller size thereof can be achieved as compared with the case that the electron multiplier section is formed along the electron emitting direction from the photocathode.

[0006]

Also, in a photomultiplier according to the present invention, it is preferable that the electron multiplier section performs electron-multiplying by bombarding the electrons with the pair of side walls forming the groove. Since the electron-multiplying is performed by bombarding the electrons with the pair of side walls

forming the groove, the electron-multiplying can be effectively performed.

[0007]

Also, in a photomultiplier according to the present invention, it is preferable that the side walls of the groove are formed with a protrusion. Since the electron-multiplying can be performed by bombarding the electrons with the protrusion formed on the side wall, the electron-multiplying can be more effectively performed.

[0008]

A photomultiplier according to the present invention comprises: a photocathode emitting electrons in response to incident light; an electron multiplier section electron-multiplies the electrons emitted from the photocathode; an anode for taking out, as a signal, the electrons multiplied in the electron multiplier section, comprises: a first glass substrate on which the anode is arranged; a second glass substrate on which the photocathode is arranged; and a silicon substrate which is arranged between the first glass substrate and the second glass substrate and on which the electron multiplier is formed, and is characterized in that the silicon substrate constitutes a vacuum envelope by being in closely contact with respective of the first glass substrate and the second glass substrate.

[0009]

In accordance with the photomultiplier according to the present invention, since the vacuum envelope is constituted by the first glass substrate, the second glass substrate, and the silicon substrate, it can be joined by not using, for example, welding, and thereby a smaller size

thereof can be achieved.

[0010]

In a photomultiplier according to the present invention, it is preferable that the silicon substrate is joined to the first glass substrate and the second glass substrate by anodic bonding. A vacuum sealing by anodic bonding can make processing steps easy.

[0011]

In a photomultiplier according to the present invention, it is preferable that the anode is arranged in a space surrounded by the silicon substrate, and is joined by anodic bonding. In the case that the anode is joined to the first glass substrate by anodic bonding, the matter that exogenous materials generate in, for example, welding can be prevented as much as possible.

[0012]

In a photomultiplier according to the present invention, it is preferable that the electron multiplier section is joined by anodic bonding. In the case that the electron multiplier section is joined by anodic bonding, the matter that exogenous materials generate in, for example, welding can be prevented as much as possible.

[0013]

A photomultiplier according to the present invention comprises: a photocathode emitting electrons in response to incident light; an electron multiplier section electron-multiplies the electrons emitted from the photocathode; an anode for taking out, as a signal, the electrons multiplied in the electron multiplier section, comprises: a first substrate on which the anode is arranged; a second substrate on which

the photocathode is formed; and a silicon substrate which is arranged between the first substrate and the second substrate and on which the electron multiplier is formed, and is characterized in that the first substrate and the silicon substrate, and, the second substrate and the silicon substrate constitute a vacuum envelope by being in closely contact with each other through a glass material, respectively.

[0014]

In accordance with the present invention, since a vacuum envelope is constituted by the first substrate, the second substrate, the silicon substrate, and the glass material, these can be joined by not using, for example, welding, and therefore a smaller size thereof can be achieved. In addition, since the first substrate and the silicon substrate, and, the second substrate and the silicon substrate are in closely contact with each other through the glass material, a vacuum envelope can be formed even when, for example, the first substrate and the second substrate are comprised of silicon.

[0015]

In a photomultiplier according to the present invention, it is preferable that the first substrate is comprised of silicon material. As comprising the first substrate with silicon material, a processing for arranging the anode can become easy.

[0016]

In a photomultiplier according to the present invention, it is preferable that the second substrate is comprised of a glass material, and the glass material between the second substrate and the silicon substrate is included in the second substrate. The second substrate is

comprised of a glass material and includes the glass material, and therefore an easier configuration can be achieved.

[Effects of the Invention]

[0017]

In accordance with the present invention, a photomultiplier capable of achieving a smaller size thereof can be provided.

[Best Modes for Carrying Out the Invention]

[0018]

The knowledge of the present invention can be understood in the light of the following detail descriptions, with reference with the attached drawings shown as an only example. Successively, embodiments of the present invention will be described with reference to the attached drawings. If available, constituents identical to each other will be referred to with numerals identical to each other without repeating their overlapping descriptions.

[0019]

Fig. 1 is a perspective view showing the exterior appearance of the photomultiplier 1a. The photomultiplier 1a comprises a first portion 2 (second glass substrate), a second portion 3 (silicon substrate), and a third portion 4 (silicon substrate). In the photomultiplier 1a, the light incident direction to a photocathode intersects the electron traveling direction in an electron multiplier section. Namely, when light is incident in a direction of arrow A of Fig. 1 and the electrons emitted from a photocathode is incident to the electron multiplier section, such a photomultiplier multiplies the electrons traveling in a direction of arrow B. Successively, the individual constituents will

now be explained.

[0020]

Fig. 2 is a perspective view showing the photomultiplier 1a shown in Fig. 1, while exploding it into the first portion 2, second portion 3, and third portion 4. The first portion 2 is constructed by a rectangular flat glass substrate 20 as a base material. The main face 20a of the glass substrate 20 is formed with a rectangular depression 201, whereas the outer periphery of the depression 201 is formed in conformity to the outer periphery of the glass substrate 20. The bottom part of the depression 201 is formed with a photocathode 22. The photocathode 22 is formed near one longitudinal end of the depression 201. The face 20b opposing the main face 20a of the glass substrate 20 is provided with a hole 202, which reaches the photocathode 22. A photocathode terminal 21 is arranged within the hole 202 and is in contact with the photocathode 22.

[0021]

The second portion 3 is constructed by a rectangular flat silicon substrate 30 as a base material. A depression 301 and a penetrating part 302 are formed from the main face 30a of the silicon substrate 30 toward its opposing face 30b. The depression 301 and penetrating part 302, each having a rectangular opening, are jointed to each other, while their outer peripheries are formed in conformity to the outer periphery of the silicon substrate 30.

[0022]

An electron multiplier section 31 is formed within the depression 301. The electron multiplier section 31 has a plurality of

wall parts 311 erected so as to extend along each other from the bottom part 301a of the depression 301. Thus, grooves are constructed between the wall parts 311. Side walls of the wall parts 311 (side walls defining the grooves) and the bottom part 301a are formed with secondary electron emitting surfaces comprised of a secondary electron emitting material. The electron multiplier section 1a includes an electron multiplier constituted by secondary electron emitting surfaces on the wall parts 311 and the bottom part 301a. Each of the wall parts 311 is provided along the longitudinal axis of the depression 301, whereas its one end is arranged with a predetermined distance from one end of the depression 301, and the other end is arranged at a position reaching the penetrating part 302. An anode 32 is arranged within the penetrating part 302. The anode 32 is arranged with a gap from inner walls of the penetrating part 302, and is fixed to the third portion 4 by anodic bonding.

[0023]

The third portion 4 is constructed by a rectangular flat glass substrate 40 as a base material. Holes 401, 402, and 403 are provided from the main face 40a of the glass substrate 40 toward its opposing face 40b. A photocathode-side terminal 41, an anode terminal 42, and an anode-side terminal 43 are inserted and fixed into the holes 401, 402, and 403, respectively. The anode terminal 42 is in contact with the anode 32 of the second portion 3.

[0024]

Fig. 3 shows a sectional view of the photomultiplier 1a. The sectional view shown in Fig. 3 is a sectional view cut by a plane along

a longitudinal direction of the photomultiplier 1a while passing through the center of thereof. As already explained, the bottom part in one end of the depression 201 in the first portion 2 is formed with the photocathode 22. The photocathode terminal 21 is in contact with the photocathode 22, whereby a predetermined voltage can be applied to the photocathode 22 through the photocathode terminal 21. The main face 20a (see Fig. 2) of the first portion 2 and the main face 30a (see Fig. 2) of the second portion 3 are joined by anodic bonding, whereby the first portion 2 and the second portion 3 are joined.

[0025]

The depression 301 and penetrating part 302 are arranged at a position corresponding to the depression 201 of the first portion 2. The electron multiplier section 31 is arranged in the depression 301 of the second portion 3, while a gap 301b is formed between one end wall of the depression 301 and the electron multiplier section 31. Accordingly, the electron multiplier section 31 of the second portion 3 is positioned directly under the photocathode 22 of the first portion 2. The anode 32 is arranged within the penetrating part 302 of the second portion 3. The anode 32 is arranged so as to be out of contact with inner walls of the penetrating part 302, whereby a gap 302a is formed between the anode 32 and penetrating part 302. The anode 32 is fixed to the main face 40a (see Fig. 2) of the third portion 4 by anodic bonding.

[0026]

The face 30b (see Fig. 2) of the second portion 3 and the main face 40a (see Fig. 2) of the third portion 4 are anodically bonded,

whereby the second portion 3 and the third portion 4 are joined. Accordingly, the first portion 2, the second portion 3, and the third portion 4 form a space therein, and a vacuum envelope is constituted by performing a vacuum airtight process when assembling the first portion 2, the second portion 3, and the third portion 4 (as will be explained later in detail).

[0027]

Since the photocathode-side terminal 401 and anode-side terminal 403 of the third portion 4 are in contact with the silicon substrate 30 of the second portion 3, a potential difference can be generated in the longitudinal direction of the silicon substrate 30 (a direction intersecting a direction in which photoelectrons are emitted from the photocathode 22) when predetermined voltages are applied to the photocathode-side terminal 401 and the anode-side terminal 403, respectively. The anode terminal 402 of the third portion 4 is in contact with the anode 32 of the second portion 3, and thus can take out electrons having arrived at the anode 32 as signals.

[0028]

Fig. 4 shows the enlarged perspective view near the wall parts 311 of the second portion 3. Side walls of the wall parts 311 arranged within the depression 301 of the silicon substrate 30 are formed with protrusions 311a. The protrusions 311a are alternately arranged on the opposing wall parts 311. The protrusions 311a are formed uniformly from the upper end to lower end of the wall parts 311.

[0029]

The photomultiplier 1a operates as follows. Voltages of

–2000 V and 0 V are applied to the photocathode-side terminal 401 and anode-side terminal 403 of the third portion 4, respectively. The resistance of the silicon substrate 30 is about 10 MΩ. The resistance value of the silicon substrate 30 can be adjusted by changing the volume thereof, e.g., the thickness thereof. For example, reducing the thickness of the silicon substrate can increase the resistance value. When light is incident on the photocathode 22 here, the photocathode 22 emits photoelectrons toward the second portion 3. Thus emitted photoelectrons are incident on the electron multiplier section 31 positioned directly under the photocathode 22. Since a potential difference is generated in the longitudinal direction of the silicon substrate 30, the incident photoelectrons are directed toward the anode 32. The electron multiplier section 31 is formed with a plurality of wall parts 311, and grooves are formed between the respective wall parts 311. Therefore, the photoelectrons incident on the electron multiplier section 31 collide against the side walls of the wall parts 311 and the bottom part 301a between the opposing side walls 311, thereby emitting a plurality of secondary electrons. The electron multiplier section 31 successively performs cascade multiplications of the secondary electrons, thereby generating 10^5 to 10^7 secondary electrons per electron reaching the electron multiplier section from the photocathode. Thus generated secondary electrons are incident on the anode 32, and are taken out as signals from the anode terminal 402.

[0030]

Successively, a method of manufacturing the photomultiplier according to the present embodiment will now be explained. In the

case of manufacturing the photomultiplier according to the present embodiment, a silicon substrate (a constituent material for the second portion 3 in Fig. 2) having a diameter of 4 inches and two glass substrates (constituent materials for the first portion 2 and third portion 4 in Fig. 2) having the same form are prepared. For each minute areas (e.g., a square of several millimeters), they are subjected to a process which will be explained in the following. When the process explained in the following ends, the resulting product is divided into individual areas, whereby a photomultiplier is completed. The processing method will now be explained with reference to Figs. 5(A) to 5(E) and 6(A) to 6(E).

[0031]

First, as shown in Fig. 5(A), a silicon substrate 50 having a thickness of 0.3 mm and a resistivity of 30 kΩ·cm is prepared, and thermally-oxidized silicon films 60 and 61 are formed on both sides of the silicon substrate 50, respectively. The thermally-oxidized silicon films 60 and 61 function as masks at the time of DEEP-RIE (Reactive Ion Etching) processing. Subsequently, as shown in Fig. 5(B), a resist film 70 is formed on the rear side of the silicon substrate 50. The resist film 70 is formed with eliminating parts 701 corresponding to the gap between the penetrating part 302 and anode 32 in Fig. 2. When the thermally-oxidized silicon film 61 is etched in this state, eliminating parts 611 corresponding to the gap between the penetrating part 302 and anode 32 in Fig. 2 are formed.

[0032]

After removing the resist film 70 from the state shown in Fig.

5(B), DEEP-RIE processing is performed. As shown in Fig. 5(C), the silicon substrate 50 is formed with gap parts 501 corresponding to the gap between the penetrating part 302 and anode 32 in Fig. 2. Subsequently, as shown in Fig. 5(D), a resist film 71 is formed on the front side of the silicon substrate 50. The resist film 71 is formed with an eliminating part 711 corresponding to the gap between the wall parts 311 and depression 301 in Fig. 2, and eliminating parts (not depicted) corresponding to the grooves between the wall parts 311. When the thermally oxidized silicon film 60 is etched in this state, an eliminating part 601 corresponding to the gap between the wall parts 311 and depression 301 in Fig. 2, eliminating parts 602 corresponding to the gap between the penetrating part 302 and anode 32 in Fig. 2, and eliminating parts (not depicted) corresponding to the grooves between the wall parts 311 in Fig. 2 are formed.

[0033]

From the state of Fig. 5(D), a glass substrate 80 is anodically bonded to the rear side of the silicon substrate 50. The glass substrate 80 has been processed beforehand with holes 801, 802, and 803 corresponding to the holes 401, 402, and 403, respectively. Subsequently, after removing the resist film 71, DEEP-RIE processing is performed on the front side of the silicon substrate 50. As shown in Fig. 6(A), a penetrating part is formed in the part processed beforehand with the gap part 501, whereby an island 52 corresponding to the anode 32 in Fig. 2 is formed. The island 52 corresponding to the anode 32 is fixed by anodic bonding to the glass substrate 80. In addition, , the groove part 51 corresponding to the grooves between the wall parts 311

in Fig. 2 and the depression 503 corresponding to the gap between the wall parts 311 and depression 301 in Fig. 2 are also formed. Here, the side walls of the groove part 51 and the bottom part 301a are formed with secondary electron emitting surfaces.

[0034]

Subsequently, as shown in Fig. 6(B), a glass substrate 90 is prepared. By spot facing, the glass substrate 90 is formed with a depression 901 (corresponding to the depression 201 in Fig. 2), and a hole 902 (corresponding to the hole 202 in Fig. 2) is provided so as to reach the depression 901 from the surface of the glass substrate 90. As shown in Fig. 6(C), a photocathode terminal 92 corresponding to the photocathode terminal 21 in Fig. 2 is inserted and fixed into the hole 902, while the depression 901 is formed with a photocathode 91.

[0035]

The silicon substrate 50 and glass substrate 80 having processed to Fig. 6(A) and the glass substrate 90 having processed to Fig. 6(C) are joined together by anodic bonding in a vacuum airtight state as shown in Fig. 6(D). Thereafter, a photocathode-side terminal 81, an anode terminal 82, an anode-side terminal 83 which correspond to the photocathode-side terminal 41, anode terminal 42, and anode-side terminal 43 in Fig. 2 are inserted and fixed into the holes 801, 802, and 803, respectively, whereby the state shown in Fig. 6(E) is obtained. Then, the resulting product is cut out into individual chips, whereby a photomultiplier having the structure shown in Figs. 1 and 2 is obtained.

[0036]

The modified example of the present embodiment will be

described with reference to Fig. 7. Fig. 7 shows a cross-sectional view of the photomultiplier 10. The photomultiplier 10 comprises a first portion 11 (second substrate), a second portion 12 (silicon substrate), a third portion 13 (glass member), and a fourth portion 14 (first substrate) which are anodically bonded together. The first portion 11 is comprised of a glass material, whose surface opposing the second portion 12 is formed with a depression 11b. A photocathode 112 is formed over substantially the whole surface of the bottom part of the depression 11b. A photocathode electrode 113 giving a potential to the photocathode 112 and a surface electrode terminal 111 in contact with a surface electrode which will be explained later are arranged at one end and the other end of the depression 11b, respectively.

[0037]

The second portion 12 is provided with a number of holes 121 parallel to the cylinder axis of the silicon substrate 12a. The inside of each hole 121 is formed with a secondary electron emitting surface. A surface electrode 122 and a back electrode 123 are arranged near opening parts at both ends of each hole 121, respectively. Fig. 7(B) shows the positional relationship between the holes 121 and surface electrodes 122. As shown in Fig. 7(B), the surface electrodes 122 are arranged so as to reach the holes 121. The same holds for the back electrodes 123 as well. The surface electrode 122 is in contact with a surface electrode terminal 111, whereas a back electrode terminal 143 is in contact with the back electrode 123. Therefore, a potential occurs in the side wall frame 12 axially of the holes 121, whereby photoelectrons emitted from the photocathode 112 advance downward

through the holes 121 in the drawing.

[0038]

The third portion 13 is a member for connecting the second portion 12 and fourth portion 14 to each other, and is anodically bonded to both of the second portion 12 and fourth portion 14.

[0039]

The fourth portion 14 is constructed by a silicon substrate 14a provided with a number of holes 141. Anodes 142 are inserted and fixed into these holes 142, respectively.

[0040]

In the photomultiplier 10 shown in Fig. 7, incident light from the upper side of the drawing is transmitted through the glass substrate of the first portion 11, so as to be incident on the photocathode 112. In response to the incident light, the photocathode 112 emits photoelectrons toward the second portion 12. The emitted photoelectrons enter the holes 121 of the third portion 13. The photoelectrons having entered the holes 121 generate secondary electrons while colliding against the inner walls of the holes 121, and thus generated secondary electrons are emitted toward the fourth portion 14. The anodes 142 take out thus emitted secondary electrons as signals.

[0041]

Successively, an analyzing module in which the photomultiplier 1a according to the present embodiment are employed will now be explained. Fig. 8(A) shows a configuration of the analyzing module 85 using the photomultiplier 1a according to the present embodiment.

The analyzing module 85 comprises a glass plate 850, a gas inlet duct 851, a gas exhaust duct 852, a solvent inlet duct 853, reagent mixing reaction paths 854, a detecting part 855, a waste reservoir 856, and reagent paths 857. The gas inlet duct 851 and gas exhaust duct 852 are provided for letting a gas to be analyzed into and out of the analyzing module 85. The gas introduced from the gas inlet duct 851 passes an extraction path 853a formed on the glass plate 850, and is let out from the gas exhaust duct 852. Therefore, when a solvent introduced from the solvent inlet duct 853 passes through the extraction path 853a, specific substances of interest (e.g., environmental hormones and fine particles) in the introduced gas if any can be extracted into the solvent.

[0042]

The solvent having passed through the extraction path 853a is introduced into the reagent mixing reaction paths 854 while containing the extracted substances of interest. There is a plurality of reagent mixing reaction paths 854, whereas their corresponding reagents are introduced from the respective reagent paths 857, so as to be mixed with the solvent. The solvents mixed with the reagents advance through the reagent mixing reaction paths 854 toward the detecting part 855 while effecting reactions. The solvents having completed the detection of substances of interest in the detecting part 855 are discharged to the waste reservoir 856.

[0043]

The structure of the detecting part 855 will be explained with reference to Fig. 8(B). The detecting part 855 comprises a

light-emitting diode array 855a, a photomultiplier 1a, a power supply 855c, and an output circuit 855b. The light-emitting diode array 855a is provided with a plurality of light-emitting diodes corresponding to the respective reagent mixing reaction paths 854 of the glass plate 850. Pumping light (indicated by solid arrows in the drawing) emitted from the light-emitting diode array 855a is introduced into the reagent mixing reaction paths 854. Solvents which may contain substances of interest flow through the reagent mixing reaction paths 854. After the substance of interest reacts with the reagents in the reagent mixing reaction paths 854, the reagent mixing reaction paths 854 corresponding to the detecting part 855 are irradiated with the pumping light, whereby fluorescence or transmitted light (indicated by broken arrows in the drawing) reaches the photomultiplier 1a. The fluorescence or transmitted light irradiates the photocathode 22 of the photomultiplier 1a.

[0044]

Since the photomultiplier 1a is provided with an electron multiplier section having a plurality of grooves (corresponding to 20 channels, for example) as has already been explained, it can detect at which position (in which reagent mixing reaction path 854), the fluorescence or transmitted light has changed. The output circuit 855b outputs the result of detection. The power supply 855c is a power source for driving the photomultiplier 1a. A thin glass sheet (not depicted) is placed on the glass plate 850, so as to cover the extraction path 853a, reagent mixing reaction paths 854, reagent paths 857 (excluding their reagent injecting parts), and the like except for

junctions of the gas inlet duct 851, gas exhaust duct 852, and solvent inlet duct 853 with the glass plate 850 and reagent injecting parts of the waste reservoir 856 and reagent paths 857.

[0045]

In accordance with the present embodiment, the electron multiplier section 31 is formed by processing grooves in the silicon substrate 30a, while the silicon substrate 30a is joined to the glass substrate 40a by anodic bonding or diffusion bonding, thus forming no vibrating parts. Therefore, the photomultiplier 1a is excellent in resistances to vibrations and shocks.

[0046]

Since the anode 32 is anodically bonded to the glass substrate 40a, there are no metal droplets at the time of welding. Therefore, the photomultiplier 1a have improved electric stability and resistances to vibrations and shocks. The anode 32 is anodically bonded by the whole lower face thereof to the glass substrate 40a, and thus does not vibrate upon shocks and vibrations. Therefore, the photomultiplier 1a have improved electric stability and resistances to vibrations and shocks.

[0047]

Also, since there is no need to assemble an inner structure, so that the handling is easy, the working time is short. They can easily attain a smaller size, since the vacuum envelope constructed by the first portion 2, second portion 3, and third portion 4 is integrated with the inner structure. Since there are no individual components inside, electrical and mechanical bonds are unnecessary.

[0048]

Since no special members are needed for sealing the vacuum envelope constructed by the first portion 2, second portion 3, and third portion 4, sealing in a wafer size is possible as in the present embodiment. Since pluralities of photomultipliers are obtained by dicing after sealing, they can be produced inexpensively by easy operations.

[0049]

Because of sealing in which no metal oxide film is necessary, no foreign matters occur. Therefore, the photomultiplier 1a have improved electric stability and resistances to vibrations and shocks.

[0050]

In the electron multiplier section 31, electrons are electron-multiplied in a cascading manner while colliding against side walls of a plurality of grooves constructed by the wall parts 311. Therefore, it is simple in structure and does not need a large number of components, and thus can easily be made smaller.

[0051]

The analyzing module 85 employing the photomultiplier 1a according to the present embodiment can detect minute particles. It can continuously perform the extraction, reaction, and detection.

[Brief Description of the Drawings]

[0052]

[Fig. 1] It is a view showing a photomultiplier according to the present embodiment.

[Fig. 2] It is a view showing a photomultiplier according to

the present embodiment.

[Fig. 3] It is a view showing a photomultiplier according to the present embodiment.

[Fig. 4] It is a view showing a photomultiplier according to the present embodiment.

[Fig. 5] It is a view for explaining a method of processing a photomultiplier according to the present embodiment.

[Fig. 6] It is a view for explaining a method of processing a photomultiplier according to the present embodiment.

[Fig. 7] It is a view showing a modified example of a photomultiplier according to the present embodiment.

[Fig. 8] It is a view showing a detecting module using a photomultiplier according to the present embodiment.

[Description of the Reference Numerals]

[0053]

1a···photomultiplier; 2···first portion; 3···second portion; 4···third portion; 22···photocathode; 31···electron multiplier section; 32···anode; and 42···anode terminal.

[Name of Document] Abstract

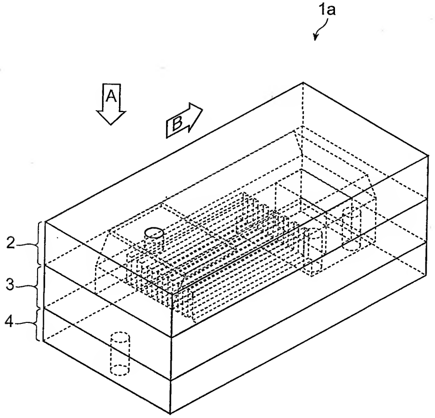
[Abstract]

[Problem] It is to provide a photomultiplier capable of achieving a smaller size thereof.

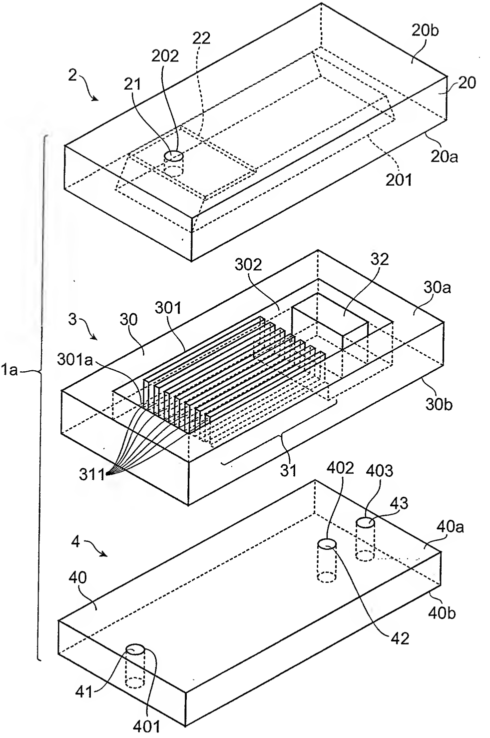
[Solving Means] The photomultiplier 1a comprises: a photocathode 22 emitting electrons in response to incident light; an electron multiplier section 31 secondary-electron-multiplies the electrons emitted from the photocathode 22; an anode 32 for taking out the electrons multiplied in the electron multiplier section, wherein the electron multiplier section 31 has grooves each extending such that the electrons travel in a direction intersecting an electron emitting direction from the photocathode, and whereby a secondary-electron-multiplying is performed by the electrons colliding against the side walls of the grooves.

[Selected Drawing] Fig. 2

~~【書類名】図面~~ [NAME OF DOCUMENT] DRAWINGS
~~【図１】~~ [Fig. 1]



~~【図2】~~ [Fig. 2]



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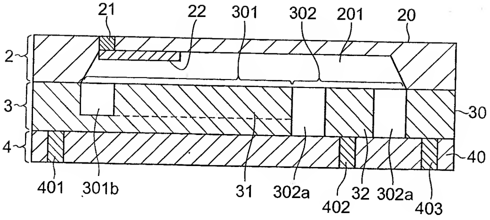
~~【図3】~~ [Fig.3]



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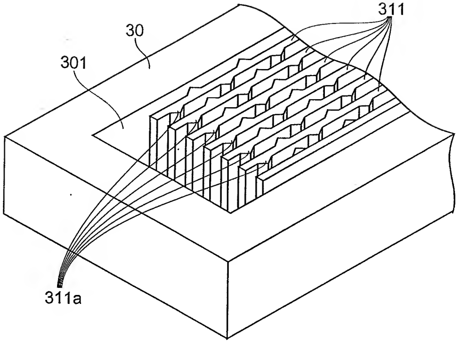
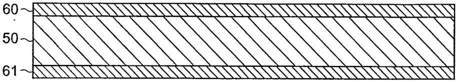
~~【図4】~~ [Fig. 4]

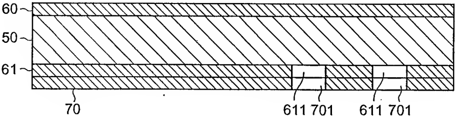


~~【図5】~~ [Fig. 5]

(A)



(B)



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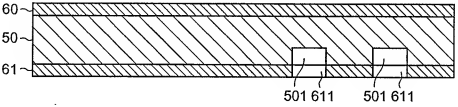

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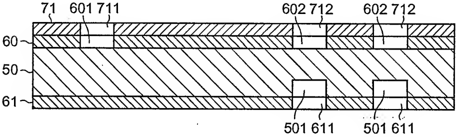

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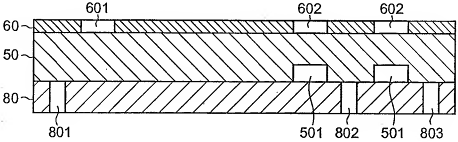

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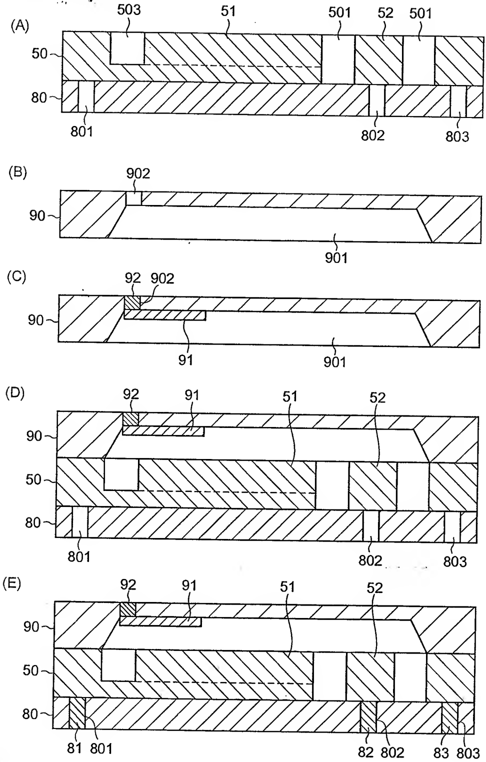
~~【図6】~~ [Fig. 6]



(A)
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(D)
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(E)
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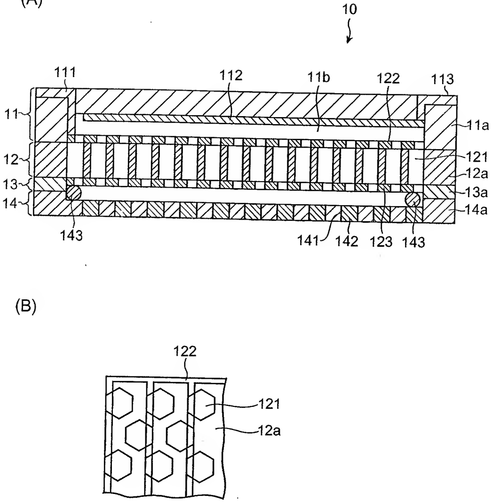
803

~~【図７】~~ [Fig. 7]

(A)

(B)



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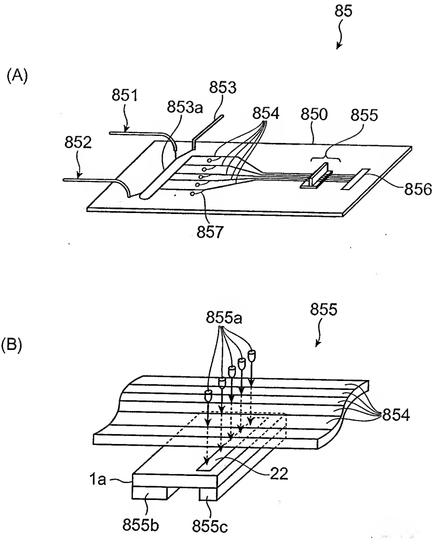
~~【図8】~~ [Fig.8]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(A)
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(B)
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